Hand-Held Cognition: Does Learning Suffer When an External Representation Interface Style Is Used?

Keith A. Beatty

Outline

- Introduction
- Literature Review
- Methodology
- Results
- Discussion
- Conclusion

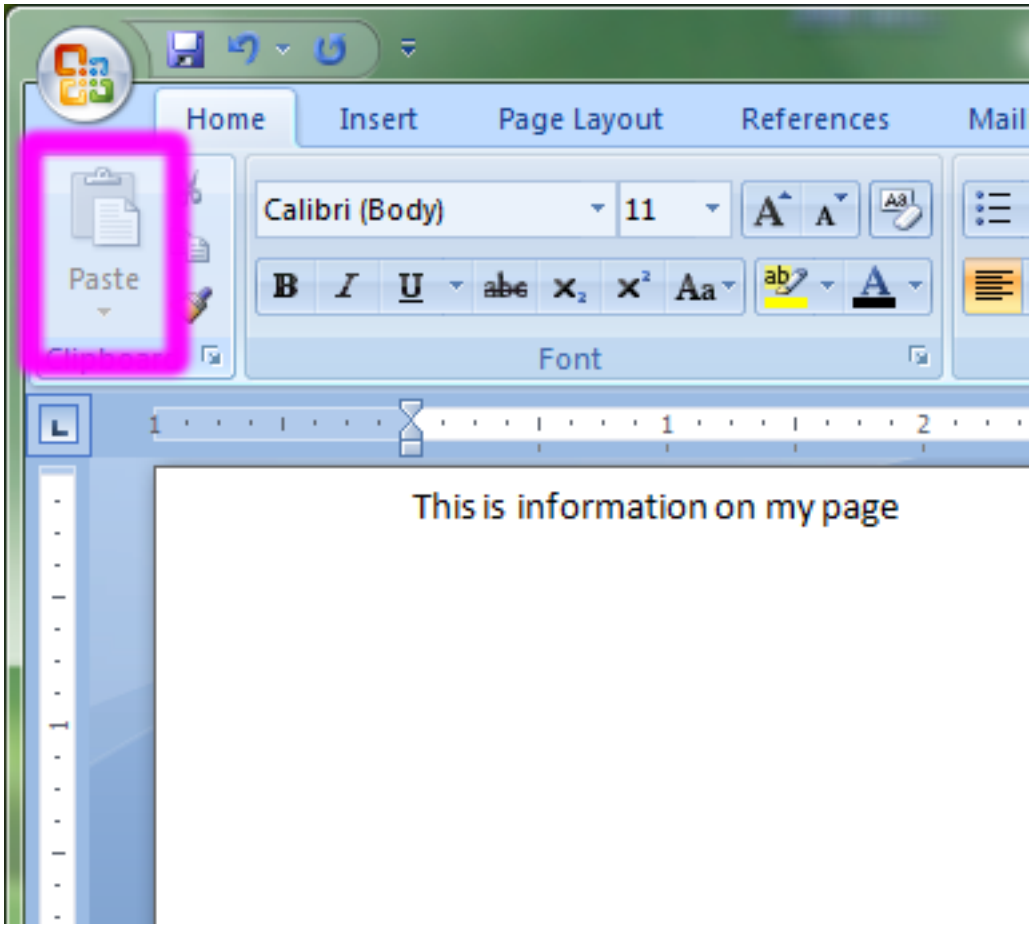
Definitions

- Internal Representation
- External Representation
- External Cognition

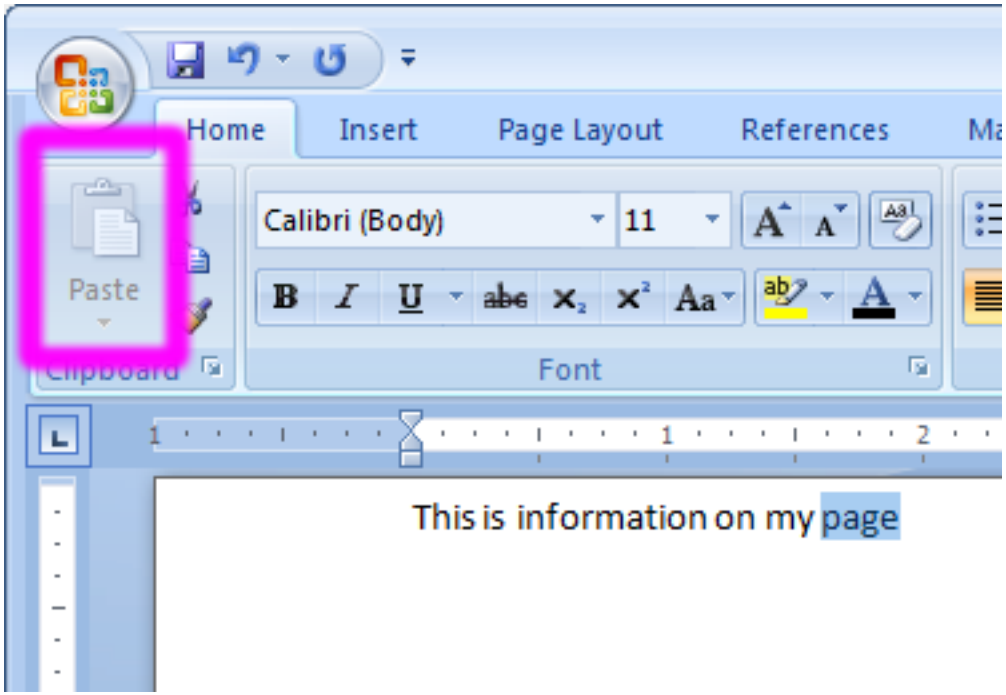
External Representations in Software

- Use of recognition in place of recall (Nielsen, 2005)
- This is done via disabling menu items, wizards, etc.

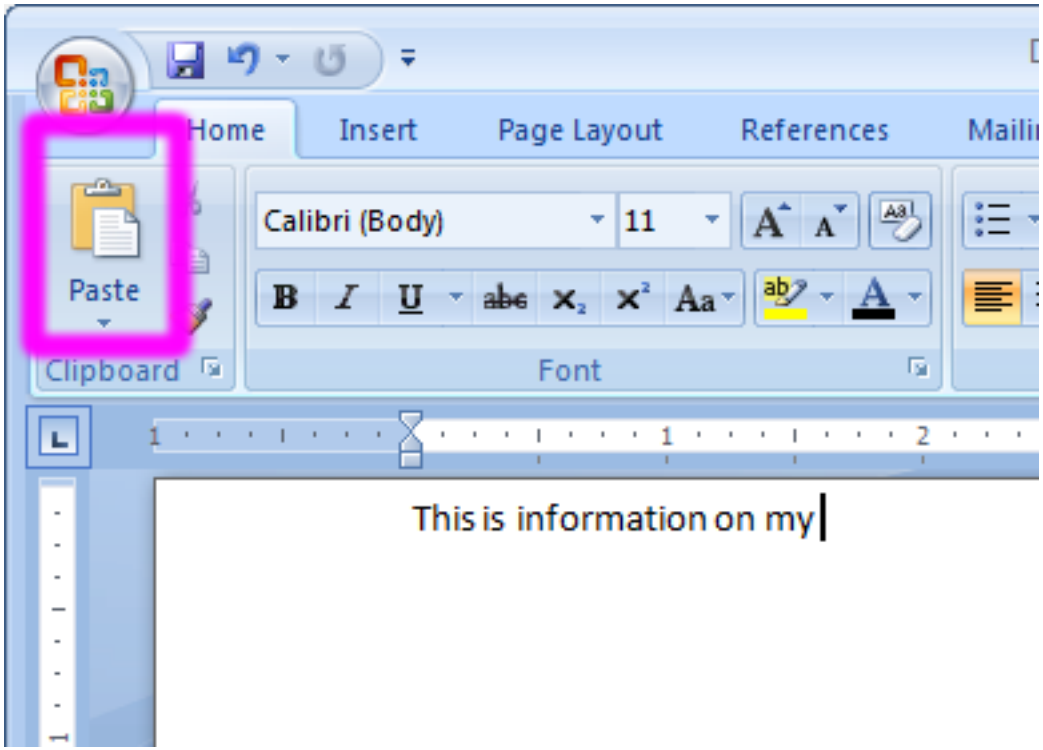
External Representation Example



External Representation Example



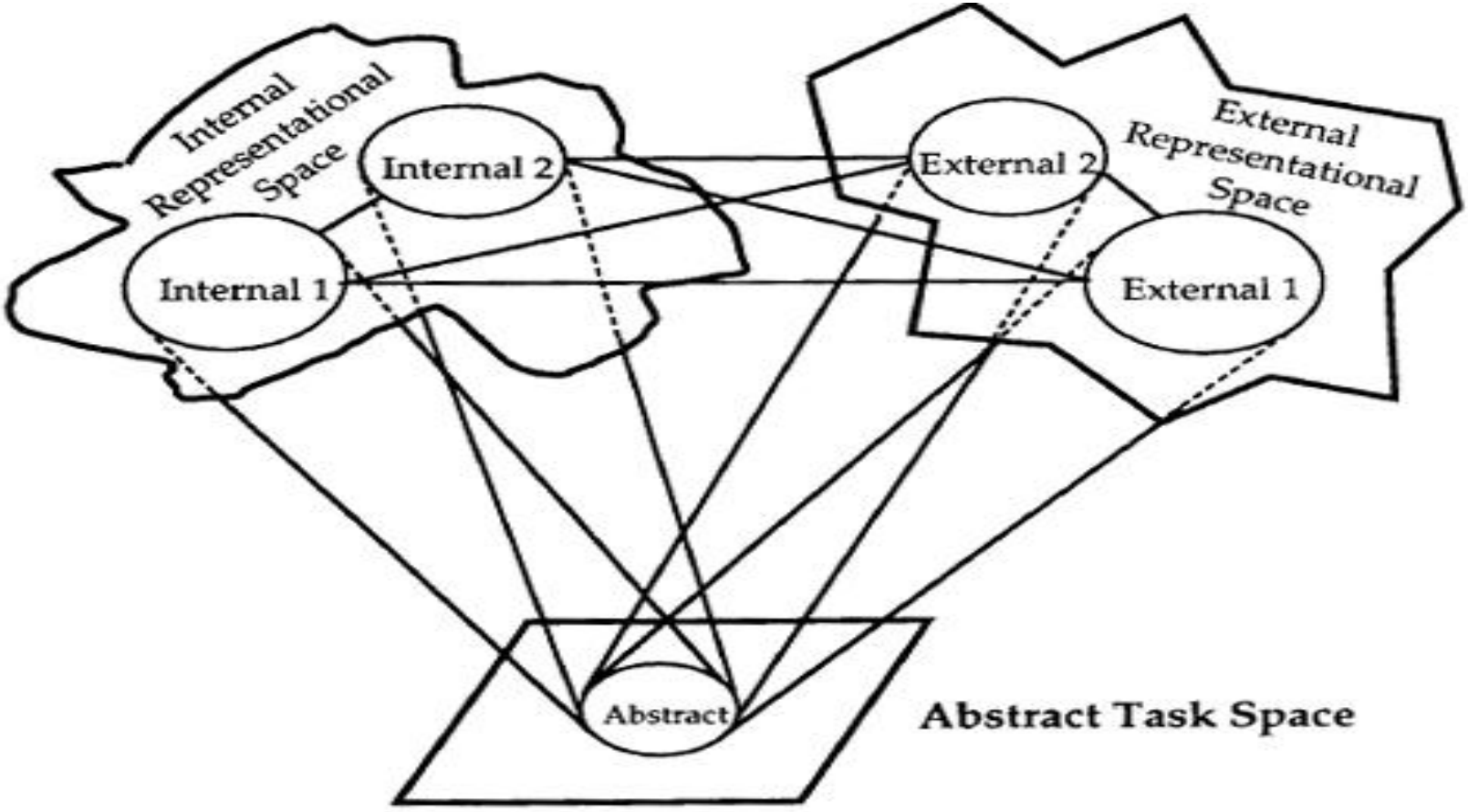
External Representation Example



Literature Review

Zhang & Norman (1994)

- Distributed Representation



(image Zhang & Norman, 1994, p. 90)

Zhang & Norman (1994)

- Study of several versions of the Towers of Hanoi logic game

Results

- External Representations
  - Memory aids
  - Anchor structure
  - Anchor learning behavior
  - May change nature of task
- External representations can be internalized
  - Not needed, if external representations always available

Mayes, Draper, McGregor & Oatley (1988), Payne (1991)

- Mayes, Draper, McGregor & Oatley (1988)
  - Effect of recall using MacWrite, a GUI based word processing program
  - Skill range: novice – skilled
  - All subject were able to use MacWrite menu's to format letters correctly
- Payne (1991)
  - Effect of recall using character and GUI based word processing programs
  - Subjects answered common questions on the word processing package that they used most

Nimwegen, Oostendorp, Tabchneck-Schijf (2004)

- Study on learning
- Created an new game based on the rules of the Missionaries and Cannibals logic game
- Rules
  - 3 cannibals / 3 missionaries / 1 boat holds 1 or 2 people
  - Cannibals will eat any missionaries when missionaries are outnumbered
  - Goal of the game to get all missionaries and cannibals to the opposite side of the river

Nimwegen, Oostendorp, Tabchneck-Schijf (2004)

- This study used 5 people, instead of the traditional 3.
- 9 trials
- Post test questionnaire, 7 procedural , 1 declarative knowledge questions about the game
- Neither time nor procedural knowledge had a significant difference
- Declarative knowledge was significantly different, where the internal representation interface style was better
- Eight months later, the originals were re-tested with a different missionaries and cannibals isomorph, with similar results as the main study

Research Hypothesis

- On a hand-held device, participants that use the internal representation interface style will have significantly more declarative knowledge than those who use the external representation interface style.

Methodology

Participants

- 31 people took part in the study
  - 19 men, 12 women
  - Age: 19 to 48, mean: 31.7
  - All had some experience w/ hand-held device, digital camera cited most often
- 21 people completed all four sessions
  - 13 men, 8 women
  - Age: 19 to 48, mean: 31.0
  - 12 assigned to internal representation interface type
  - 9 assigned to external representation interface type

Design

- Between subjects
- Participant assigned to a group: representation interface style
- New game that used the Missionaries and Cannibals game rules on a smart phone
- 4 sessions, 6 to 8 days apart
  - 1st session, 6 trials: trial 1 & 2 are used to train, 4 remaining trials are "normal"
  - 2, 3 and 4 sessions – 4 trials

Implementation - Game

Comparison between interface styles

- Internal Representation

- External Representation

Implementation - Game

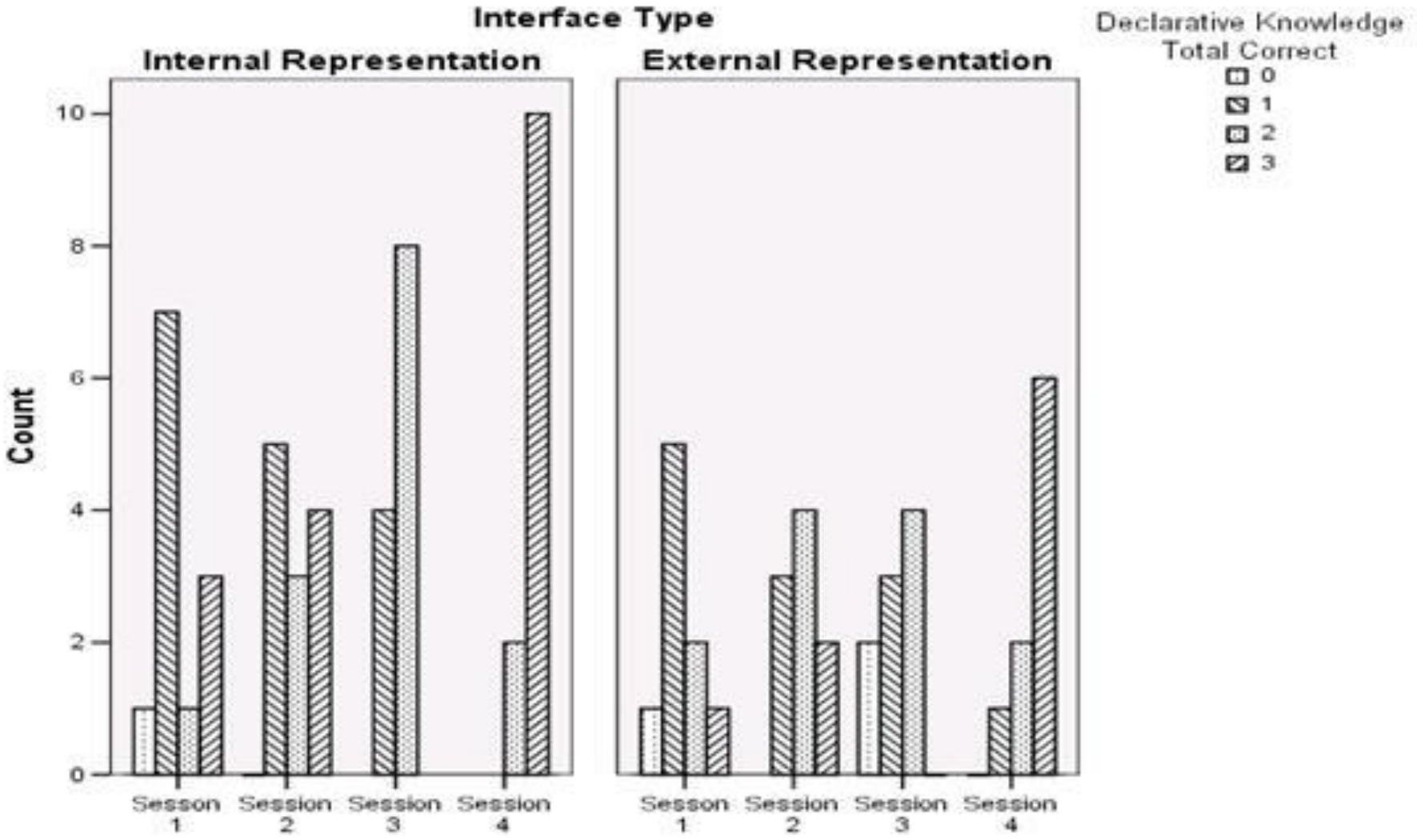
Instructional video given to the participants

Statistical Tests

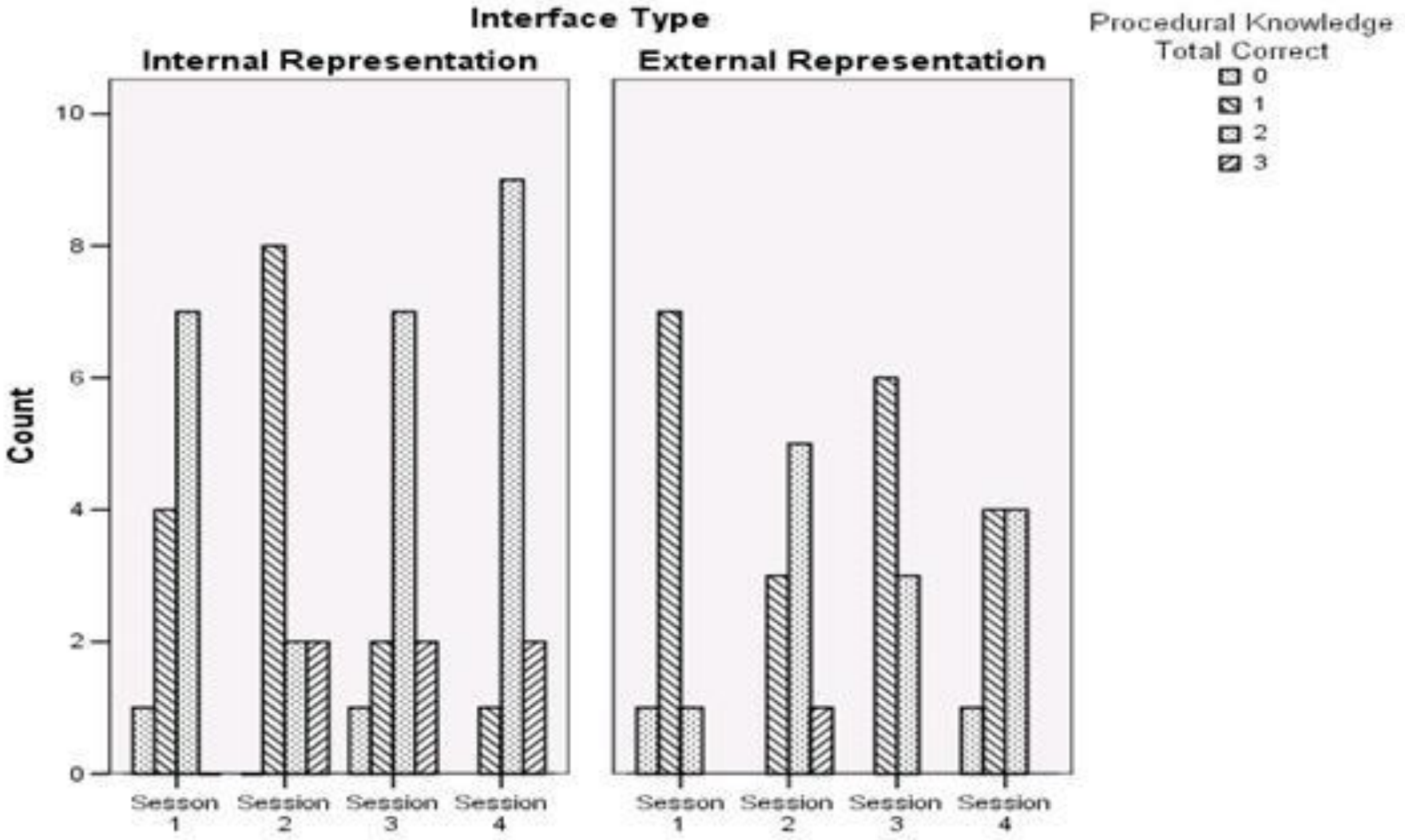
- Non-parametric tests used, because of range of data
- Pearson's Chi-squared Test for Independence used for categorical types:
  - Declarative
  - Procedural
- Mann-Whitney U test – non-parametric version of the Student *t* test
- Significance level of .05 or less is considered a significant result

Results

Results – Declarative Knowledge



Results – Procedural Knowledge



Discussion

- Declarative / Procedural Chi-Squared Results
- Declarative Results
- Procedural Results
- Qualitative Results
- Summary Count Mann Whitney U Selected Results

Post-Survey Qualitative and Quantitative Chi-Squared

- Contingency tables for Declarative and Procedural knowledge questions had cells that did not total up to 5, so that the Chi-square result would be unreliable.
- Declarative and Procedural results are reviewed using Means and Standard Deviations

Post Session Questionnaire Declarative & Procedural Mean and Standard Deviation Results

Group		Declarative Knowledge		Procedural Knowledge	
		M	*SD*	*M*	*SD*
Internal	Session 1	1.50	1.00	1.50	0.67
External	Session 1	1.33	0.87	1.00	0.50
Internal	Session 2	1.92	0.90	1.50	0.80
External	Session 2	1.89	0.78	1.78	0.67
Internal	Session 3	1.67	0.49	1.83	0.84
External	Session 3	1.22	0.83	1.33	0.50
Internal	Session 4	2.83	0.39	2.08	0.51
External	Session 4	2.56	0.73	1.33	0.71

Summary Count Mann-Whitney U Results, Session 1

		Time		Non-Object Moves		Invalid Moves		Object Moves	
			Exact Sig.		Exact Sig.		Exact Sig.		Exact Sig.
Grouping		U	1-tailed	U	1-tailed	U	1-tailed	U	1-tailed
Session 1									
	Trial 3	33.50	0.08	37.50	0.13	33.50	0.08	31.50	0.06
	Trial 5	35.00	0.09	35.00	0.09	40.50	0.18	20.50	0.01
	Trial 6	28.50	0.04	32.00	0.06	33.50	0.08	26.50	0.03
Session 1 – w/o 2X outliers									
	Trial 3	23.50	0.05	25.50	0.07	21.50	0.03	31.50	0.06
	Trial 5	27.00	0.09	27.00	0.06	31.50	0.16	20.50	0.01
	Trial 6	22.50	0.04	25.00	0.06	23.50	0.05	26.50	0.04

Summary Count Mann-Whitney U Results, Session 1 Screens

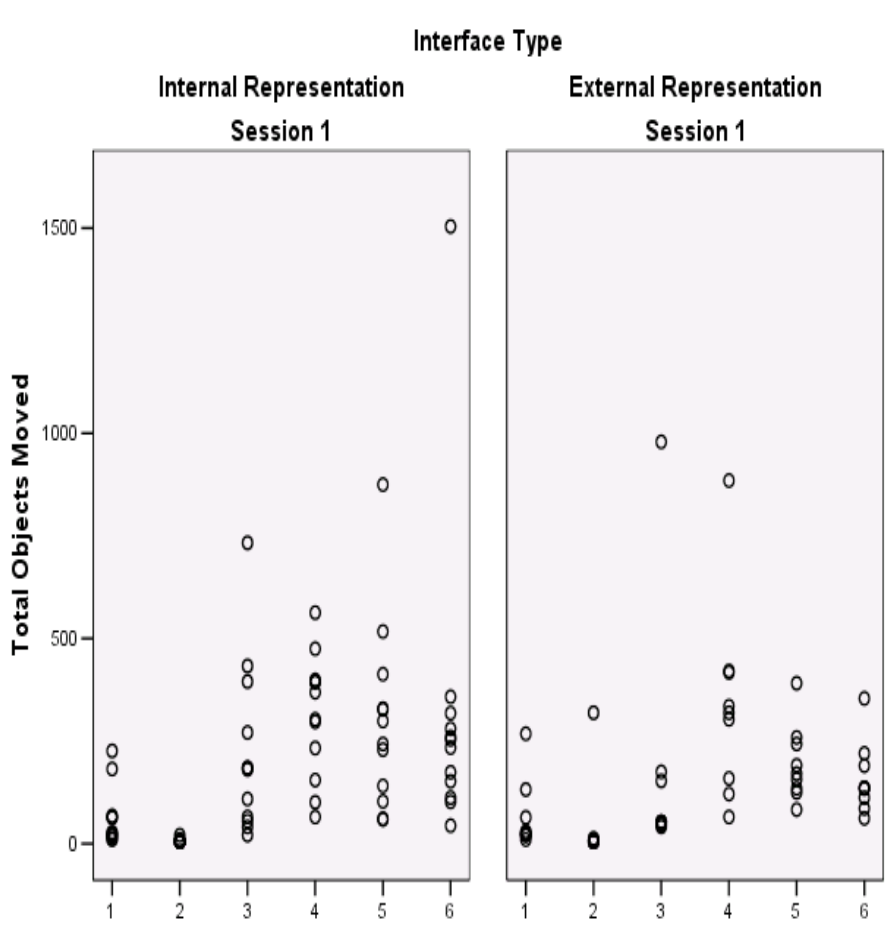
Trial 3

Trial 5

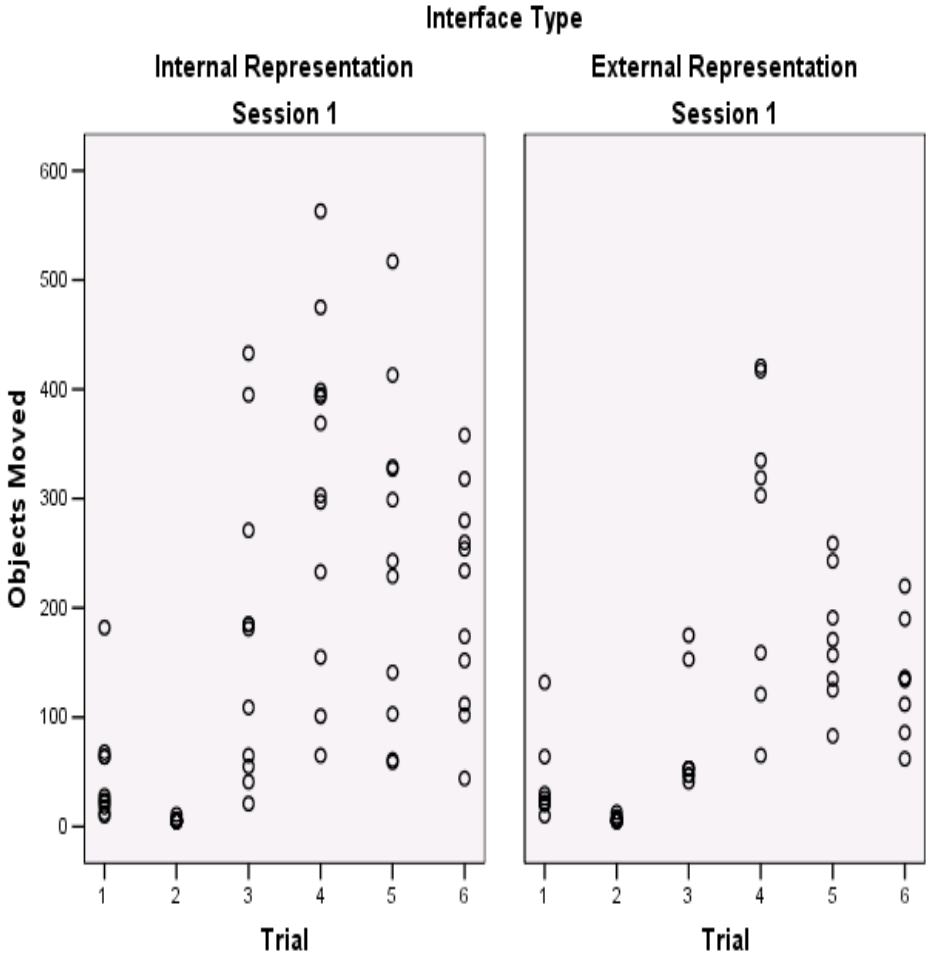
Trial 6

Summary Count Mann-Whitney U Results, Session 1, Trial 5, 6 - Object

- With Outliers

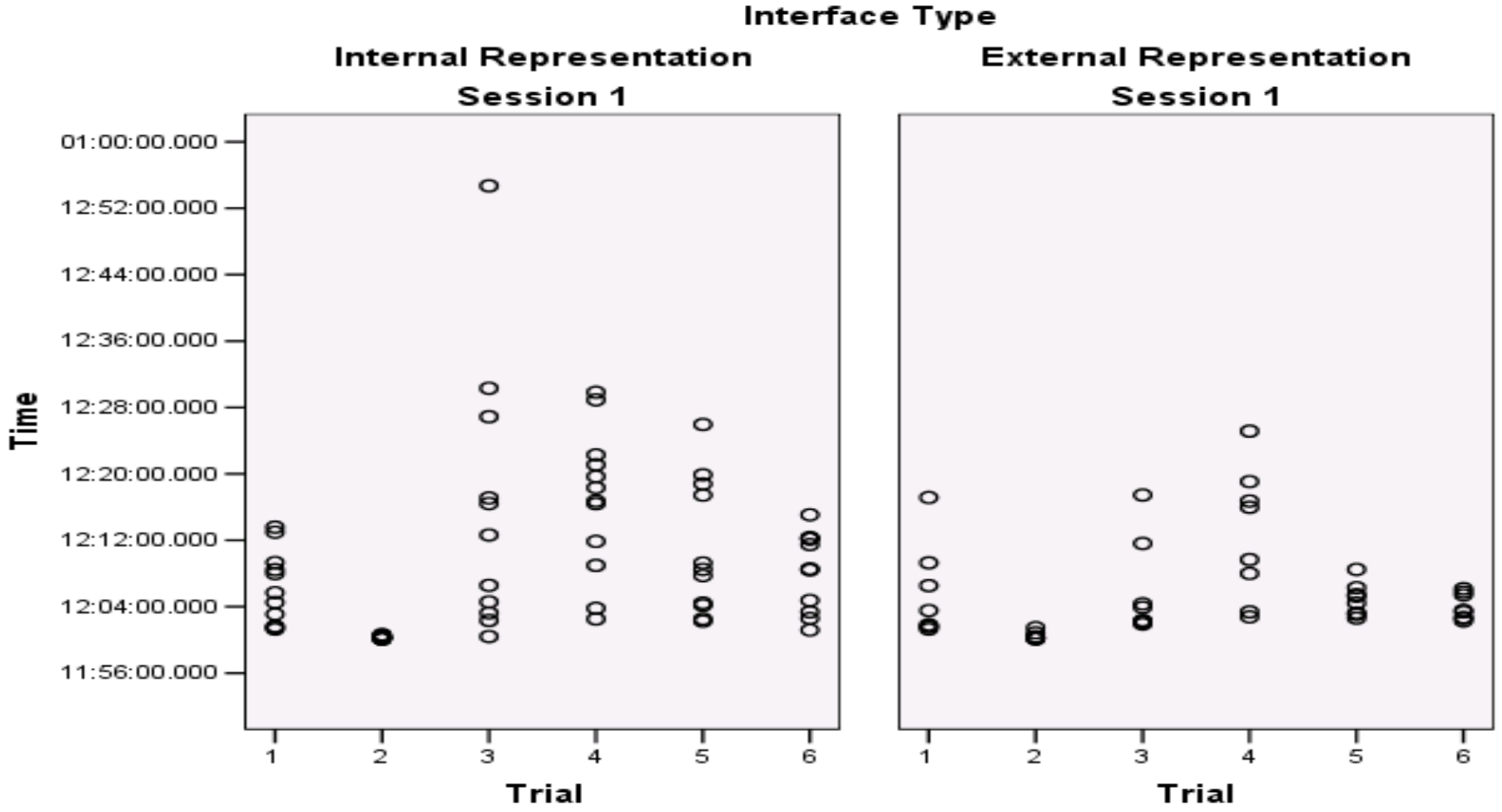


- With 2X Outliers removed



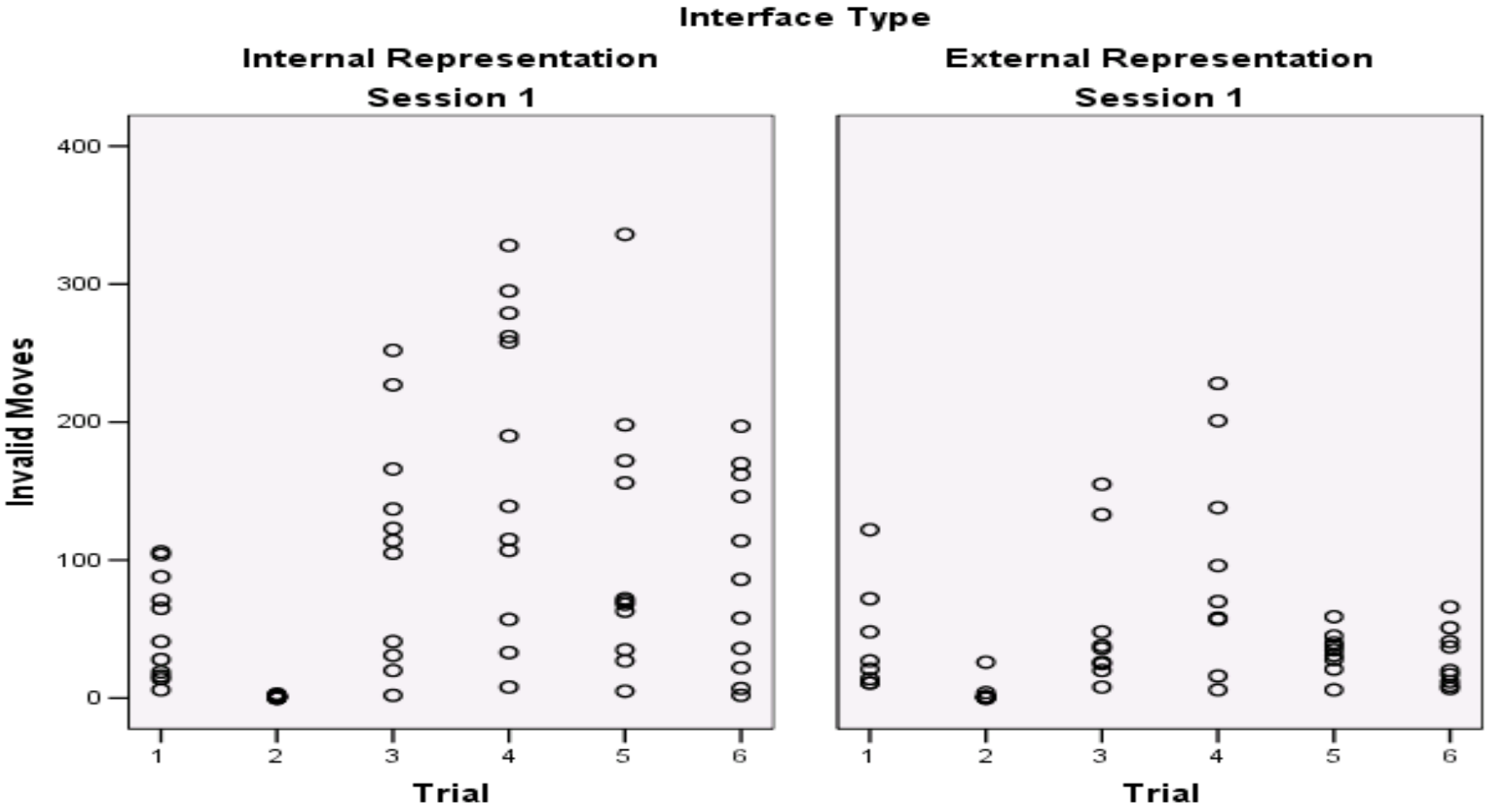
Summary Count Mann-Whitney U Results, Session 1, Trial 6 - Time

Has two times standard deviation outliers removed



Summary Count Mann-Whitney U Results, Session 1, Trial 6 - Invalid

Has two times standard deviation outliers removed



Summary Count Mann-Whitney U Results, Session 2

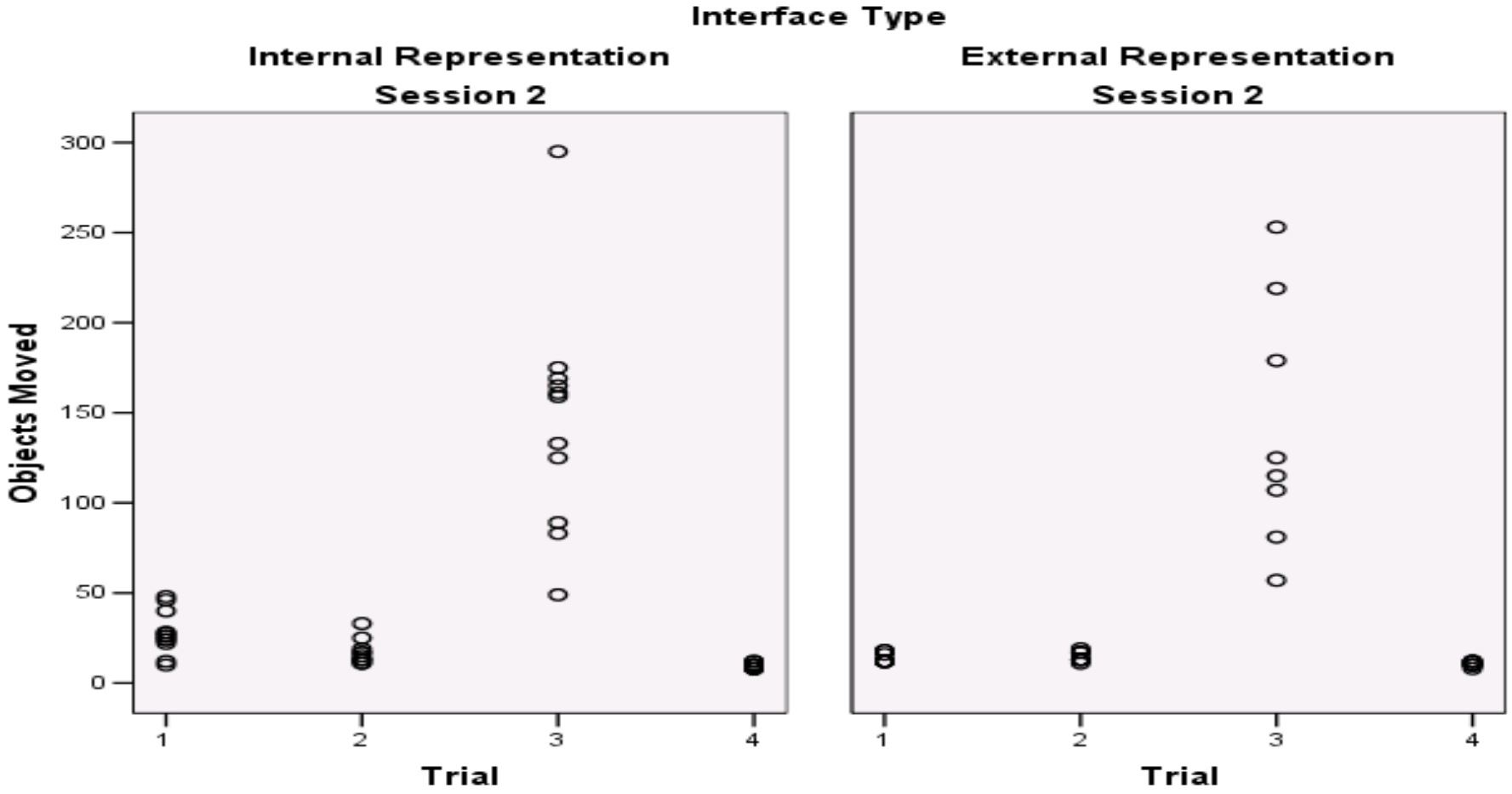
		Time		Non-Object Moves		Invalid Moves		Object Moves	
			Exact Sig.		Exact Sig.		Exact Sig.		Exact Sig.
Grouping		U	1-tailed	U	1-tailed	U	1-tailed	U	1-tailed
Session 2									
	Trial 1	20.50	0.01	15.50	0.02	22.50	0.01	11.00	0.00
	Trial 3	41.50	0.20	41.50	0.20	53.50	0.49	30.00	0.05
Session 2 – w/o 2X outliers									
	Trial 1	20.50	0.01	9.50	0.00	13.50	0.00	11.00	0.00
	Trial 3	29.50	0.12	29.50	0.12	41.50	0.44	19.00	0.02

Summary Count Mann-Whitney U Results, Session 2, Trial 3 - Object

- Trial Screen for session 2, trial 3 & session 3, trial 3

Summary Count Mann-Whitney U Results, Session 2, Trial 3 - Object

Has two times standard deviation outliers removed

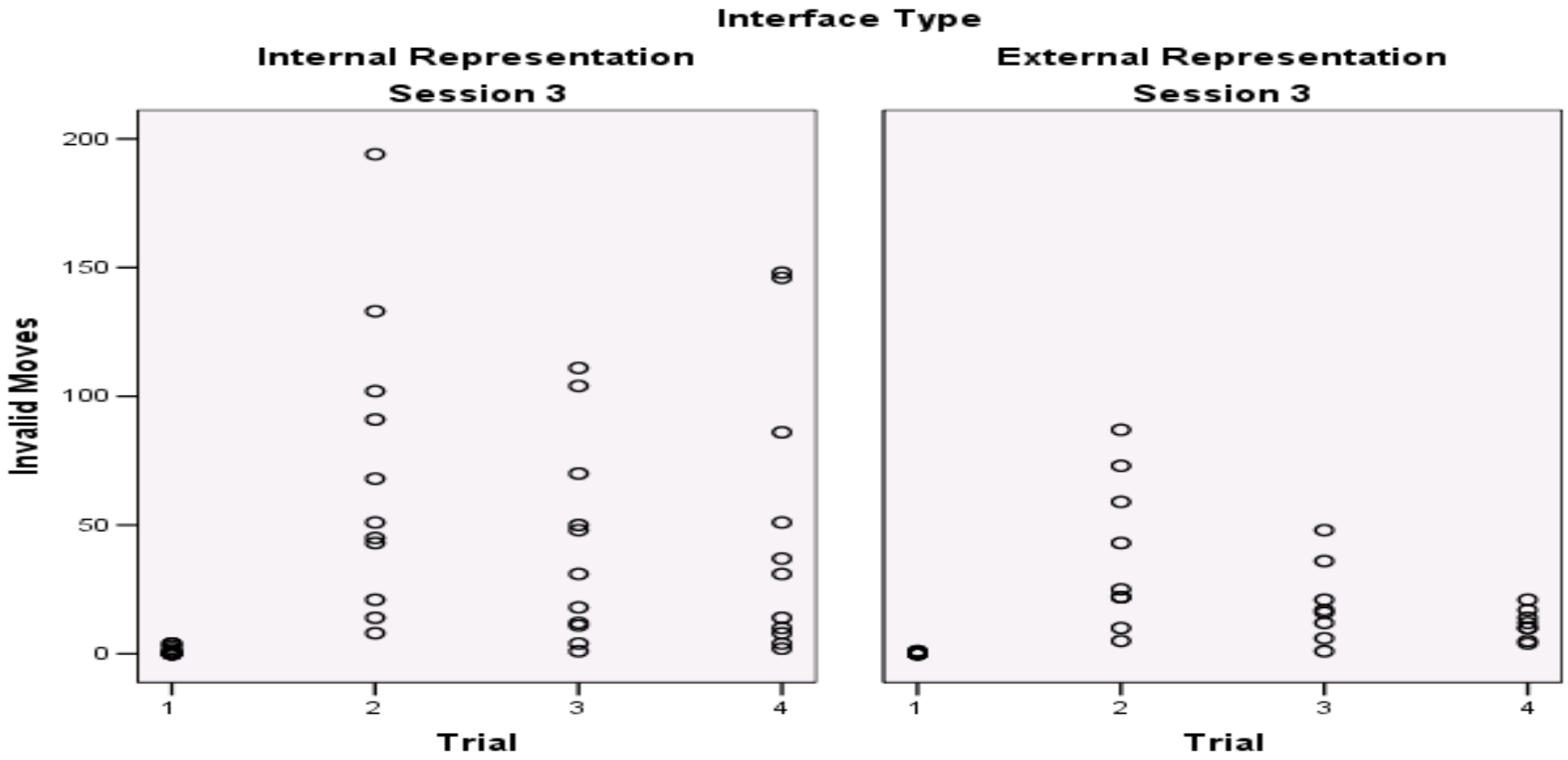


Summary Count Mann-Whitney U Results, Sessions 3

		Time		Non-Object Moves		Invalid Moves		Object Moves	
			Exact Sig.		Exact Sig.		Exact Sig.		Exact Sig.
Grouping		U	1-tailed	U	1-tailed	U	1-tailed	U	1-tailed
Session 3									
	Trial 1	32.00	0.06	23.50	0.01	33.50	0.06	43.00	0.22
	Trial 3	45.50	0.28	40.50	0.18	28.50	0.04	42.50	0.22
Session 3 – w/o 2X outliers									
	Trial 1	22.50	0.02	12.00	0.00	24.00	0.02	32.00	0.10
	Trial 3	36.50	0.28	31.50	0.16	20.50	0.03	31.50	0.16

Summary Count Mann-Whitney U Results, Session 3, Trial 3 – Invalid

Has two times standard deviation outliers removed



Conclusion

- Study Limitations
- Future Research

Study Limitations

- Low number of participants
  - Longitudinal nature of study limited participation
  - Required interaction with a proctor
  - Length of study
  - Budget

Future Research

- Larger budget to recruit more participants
- Change program to record individual movements
- Change program to vary objects (5 / 4 / 3)
- Use newer / easier to use smart phones – iPhone, Google Android based G-1

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Questions?